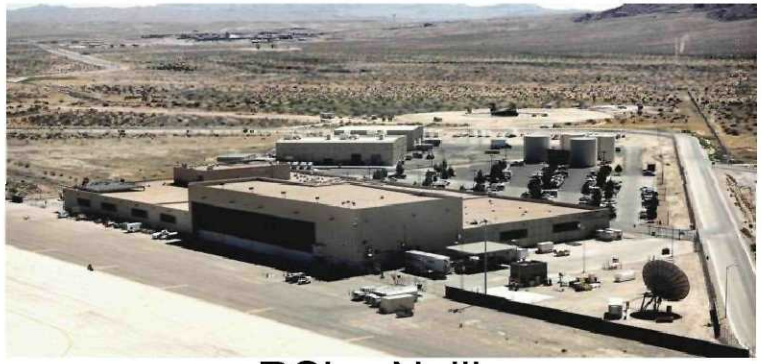
Florida Phosphate Mine
Pilot Study Aerial Radiological Survey

U.S. Department of Energy
National Nuclear Security Administration
Remote Sensing Laboratory (RSL)

RSL - Andrews



RSL - Nellis

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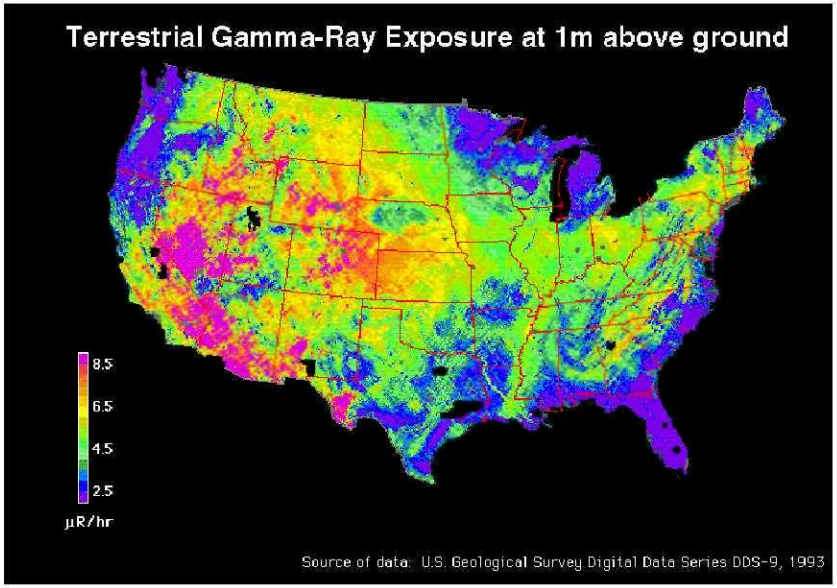
Prior Baseline Radiological Surveys

National Uranium Resource Evaluation (NURE) Program



- 1970s to early 1980s the United States Government sponsored aerial radiometric and aero-magnetic surveys over the entire United States
- Purpose of the program was to identify GENERAL regions with potential for mining uranium
- In 1981, EG&G Geometrics flew a fixed-wing aircraft equipped with an array of sodium iodide scintillation detectors over the north central region of Florida
- Survey Flight Parameters
  - Altitude: 500 feet
  - Line Spacing: 6 miles
- Data collected sampled only 3% of the over-flown area
- Previous studies in Florida and elsewhere have utilized the NURE data effectively to define WIDE AREA radon potential but in no way does the NURE data approach the sensitivity, spatial resolution, and 100% areal coverage as proposed by the Pilot Study Aerial Radiological Survey.

Prior Baseline Radiological Surveys

Florida Department of Health (FDOH) Historical Data

- Data collected as part of a FDOH monitoring program conducted from mid-1970's to mid-1990's
- Shows a wide variation in exposure background levels generally ranging from 6 to 50 µR/h with some levels approaching 100 µR/h.
- Majority of data was collected from residential subdivisions but data was also available for two commercial sites.
- Preliminary review of the data was conducted and found to be very informative. Several residential areas were noted and their geographic locations were marked for further study.

Prior Baseline Radiological Surveys

Florida Statewide Radiation Study (Publication No. 05-029-057, 12/87)

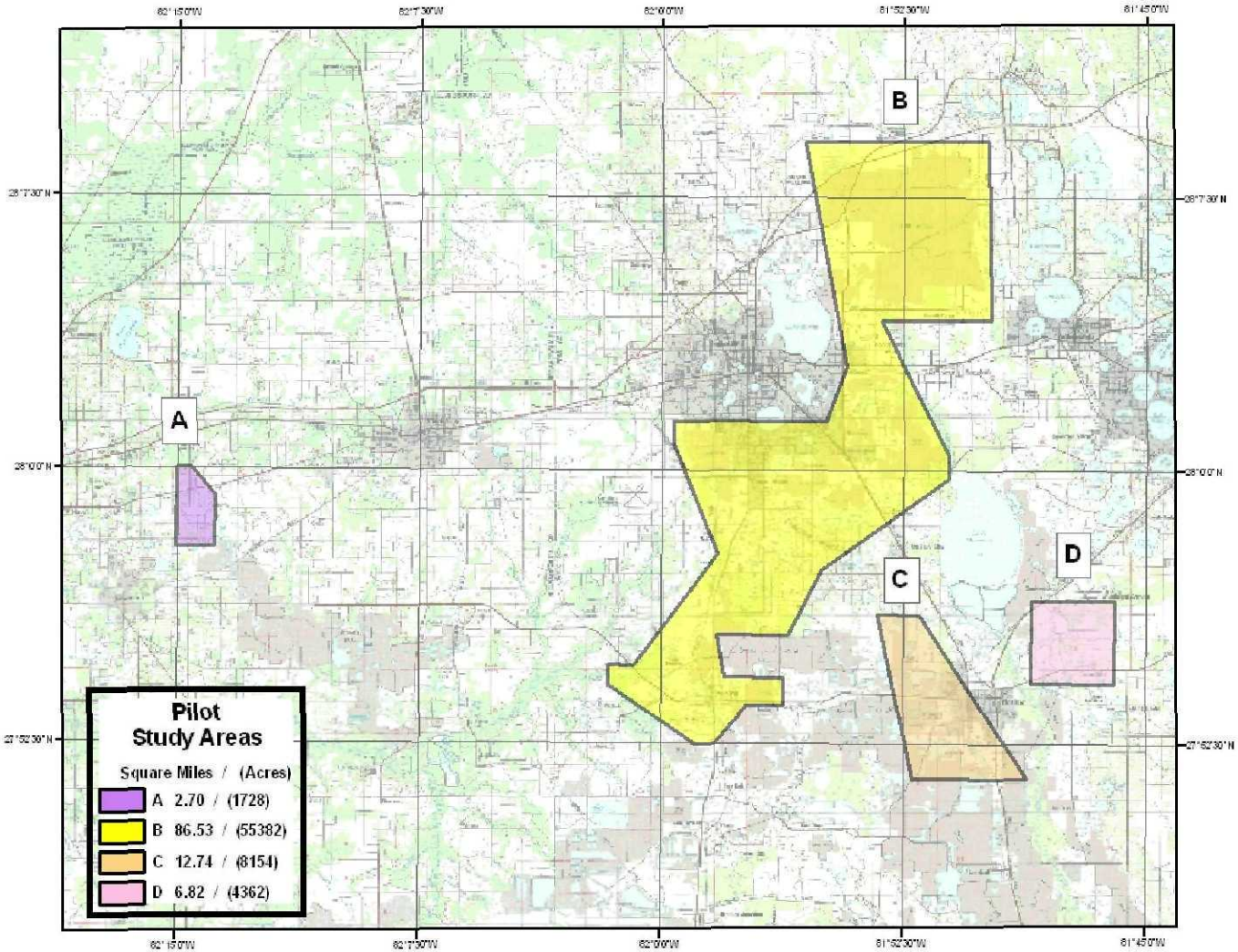
- In 1986-87, this study was conducted by GEOMET Technologies, Inc. under contract to the Florida Institute for Phosphate Research.
- Well over 6,000 Florida homes were surveyed for indoor radon concentrations. Homes in every county in the state were included.
- In half the homes, radon gas in soil and gamma radiation levels both indoors and out were measured.
- Besides new measurements, historical data (which includes the NURE data and the EPA's report entitled "Indoor Radiation Exposure Due to Radium-226 in Florida Phosphate Lands") were compiled and assessed.
- The study found that 7% of the state's land, located in 18 counties, showed definite evidence of elevated radon potential. Also, limited evidence of elevated levels were found in parts of an additional 14 counties.
- A preliminary review of this report was conducted and the report was found to be very informative. The data helps to reinforce the selection of the survey areas-of-interest for the proposed Pilot Study.

Prior Baseline Radiological Surveys

Use of Legacy Baseline Radiological Data

- Useful in providing an indication of the exposure levels to be expected in any regional suspect areas-of-interest.
- Will aid in the selection and bounding of any new aerial and detailed ground-based radiological surveys.
- Due to the age of the data and the density of the sampling employed:
  - Areas previously sampled may have been drastically altered due to recent population growth and building construction. Thus, the reliability of the old data is reduced.
  - Previous areas not sampled, but which have a potential radon problem, may go undetected.
- Hence, new measurements (aerial and ground-based) should be made in order to obtain a more accurate overview of any and all potential radon problem areas. This new data will limit the size of any remediation work to be conducted.

Proposed Pilot Study Aerial Radiological Survey Sites



- 4 Survey Areas – 108.8 mi^2 (~ 69,600 acres)
- Bell-412 Helicopter with twelve 16-x 4-x 2-in. NaI(T*l*) log detectors
- Survey Parameters
  - Altitude: 150 feet
  - Line Spacing: 250 feet
  - Ground Speed: 80 knots
- Total # Flights: 23 (58 flight hours)
- Total # Field Days: 21 (includes deploy/return legs and weather permitting)

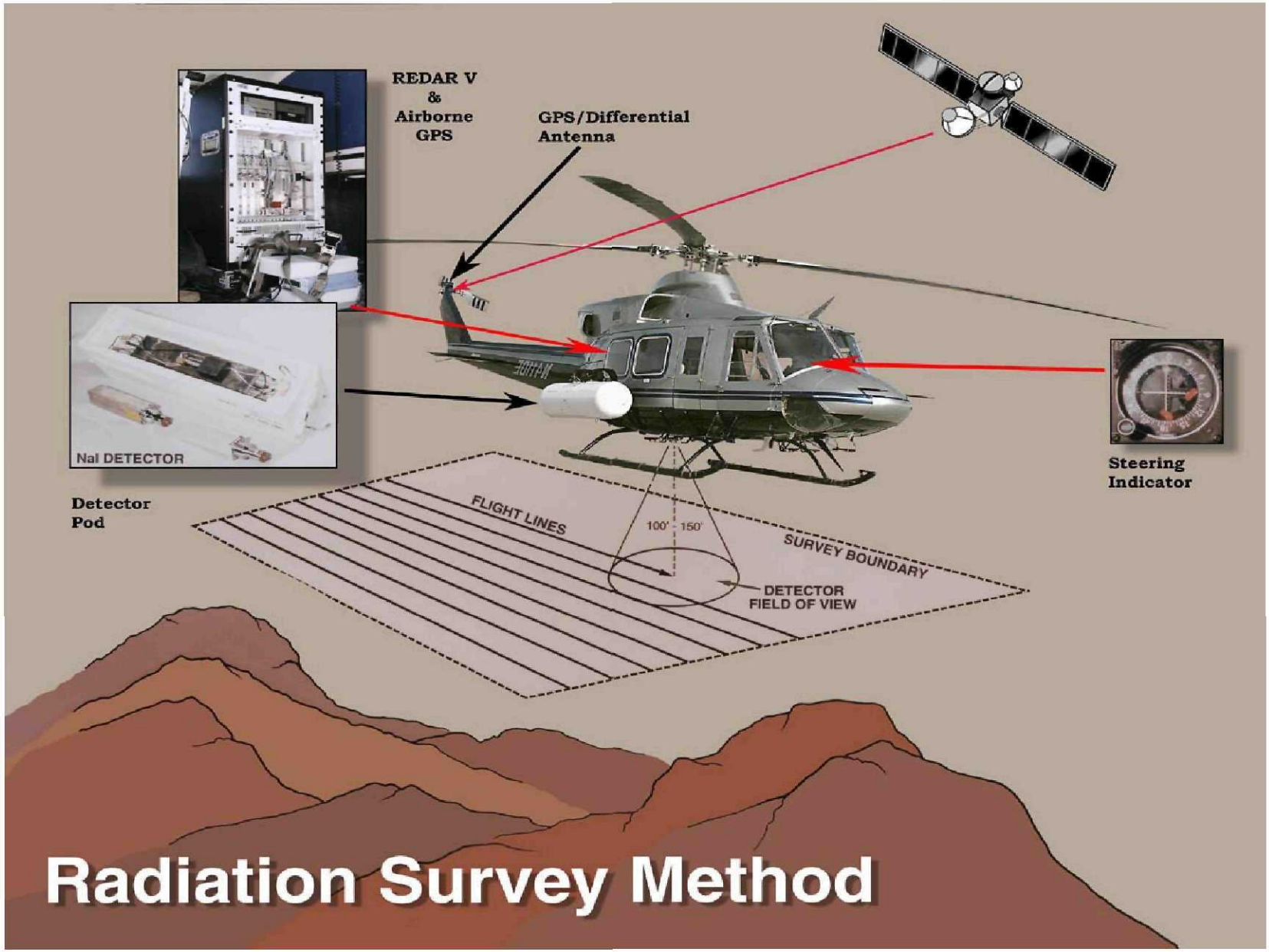
Mission Equipment – Data Recording

REDAR V (Radiation and Environmental Data Acquisition and Recorder System)

- Multi-processor data acquisition system custom designed by the RSL
- Displays radiation and positional information in real-time
- Archival gamma-ray spectra, aircraft position, meteorological parameters, and real-time clock

Sodium Iodide (NaI[Tl]) Detector Pods

- Contain 12 detectors 16- x 4 x 2-inch log-type thallium-activated sodium iodide scintillation detectors
- Output is full-energy spectra collected each second


REDAR V
&
Airborne
GPS
GPS/Differential
Antenna
NaI DETECTOR
Detector
Pod
Steering
Indicator
FLIGHT LINES
100'
150'
SURVEY BOUNDARY
DETECTOR
FIELD OF VIEW
Radiation Survey Method

AMS Aerial Survey Sensitivity [a,b]

Altitude (feet)	Point Source Minimum Detectable Activity (MDA)[c]		Uniform Soil [d] (pCi/g)	Surface Deposition (μCi/m²)
	No Offset (mCi)	Midway (mCi)		
150	1.7	4.9	1.5	0.33
500	28.0	120.0	3.0	0.66

[a] Twelve 16- x 4- x 2-in. NaI (Tl) detectors; Line spacing equals to 2 x Altitude

[b] Ra-226 MDAs based on the detection of Bi-214 in assumed equilibrium with parent Ra-226.

[c] Amount detected within detector's field of view, whose radius is approximately the altitude. "No Offset" refers to flying directly over the source, whereas "Midway" equates to a lateral displacement equal to the altitude.

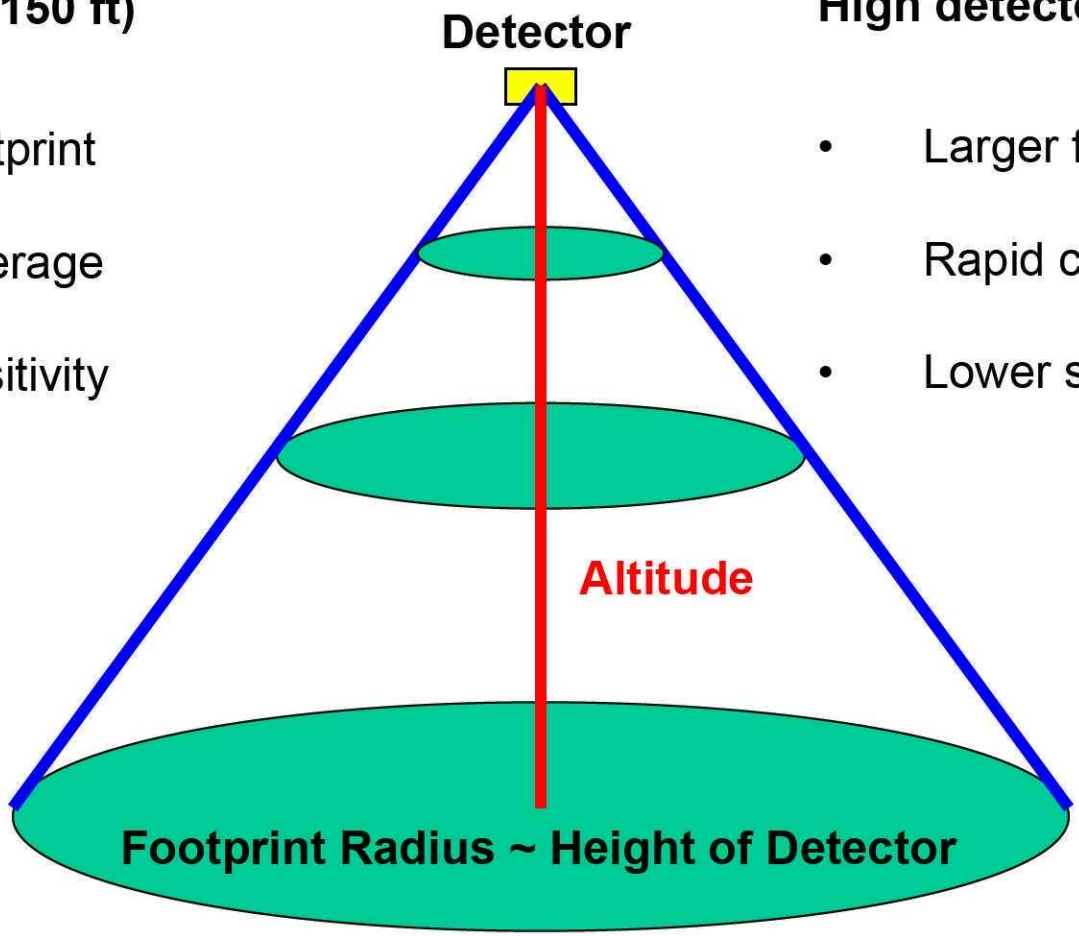
[d] Other depth profiles generally have greater sensitivity, but overburden will hamper sensitivity.

AMS

Altitude Considerations

Low detector (~150 ft)

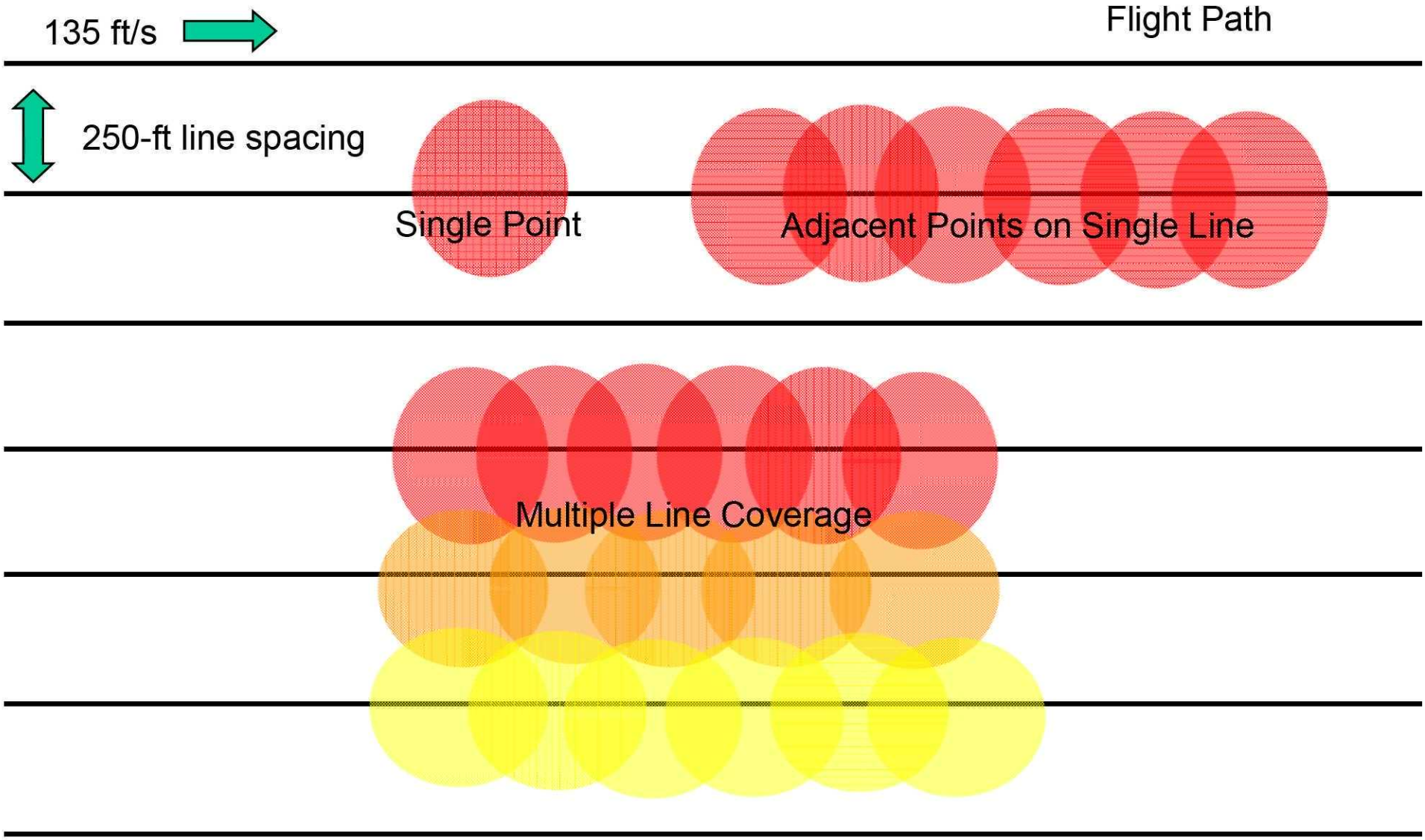
- Smaller footprint
- Slower coverage
- Higher sensitivity

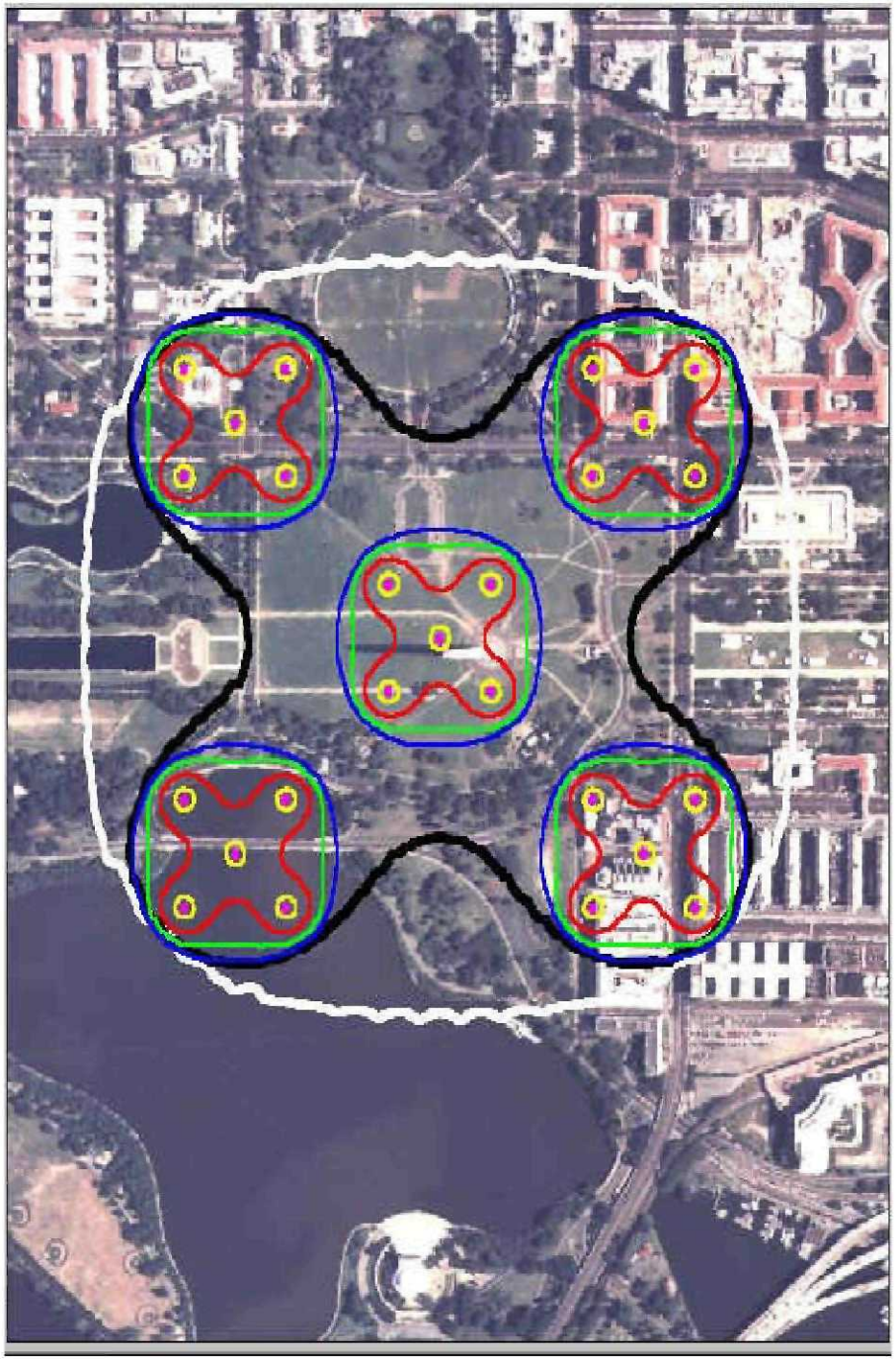


High detector (~500 ft)

- Larger footprint
- Rapid coverage
- Lower sensitivity

Aerial Footprint





AMS Helicopter Sensitivity & Resolution

Model of 25 ^{137}Cs sources

KEY	Altitude (ft)	MDA[a]	Exposure Rate[b,c]	
White	3000	281 Ci	107 R/h	Lethal in 3 hours
Black	1000	82 mCi	30 mR/h	Health effects in a month
Blue	500	8 mCi	3 mR/h	1.2 X occupational limit
Green	300	2 mCi	0.8 mR/h	0.3 X occupational limit
Red	150	300 µCi	115 µR/h	19X background
Yellow	50	30 µCi	12 µR/h	2X background

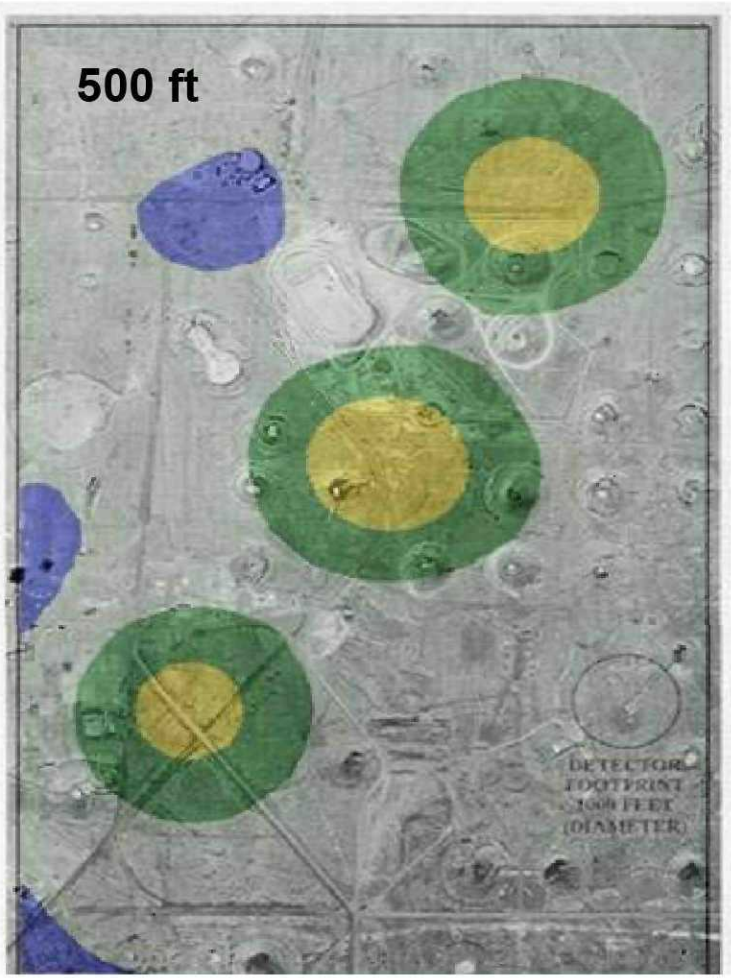
[a] MDA for a single point source (not array element)

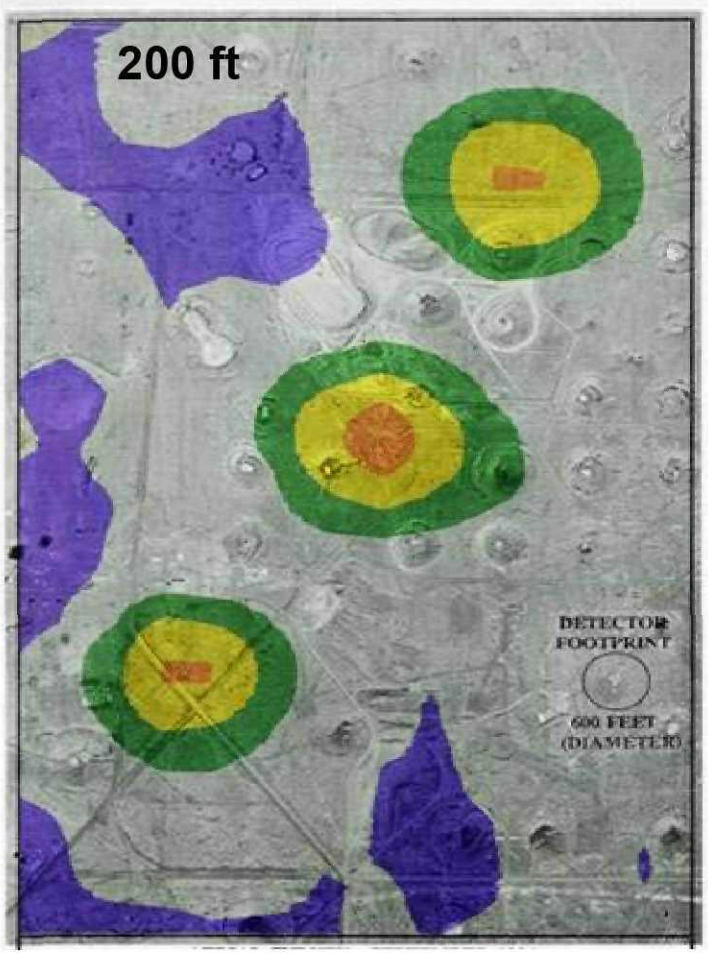
[b] Exposure rate at one-meter for a single source at the MDA limit

[c] Background is 6 µR/h for these calculations

AMS Aerial Sensitivity

Effect of Altitude – Nevada Test Site Area 3





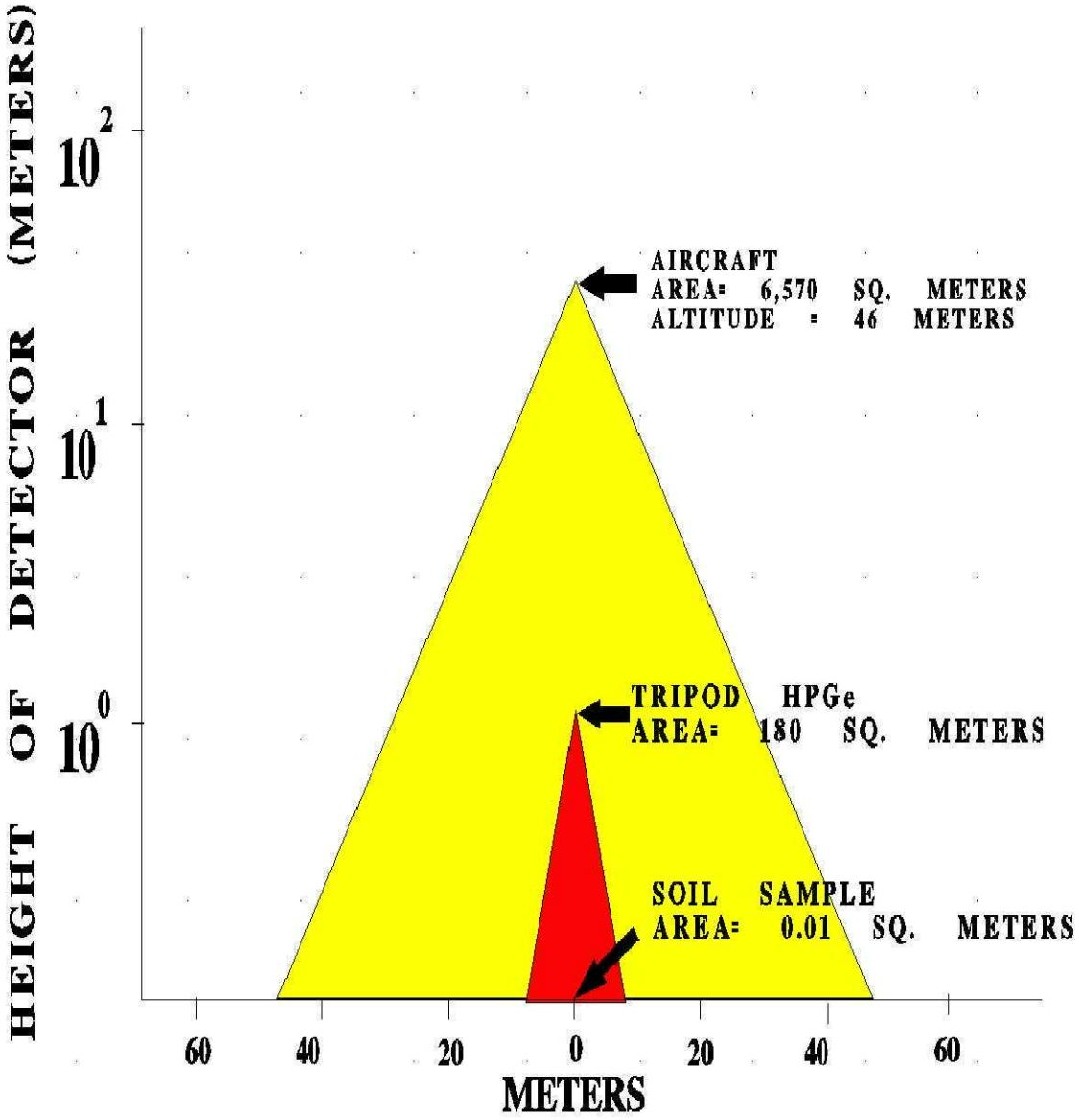
Estimated External Exposure Rate

7-15 μR/h
15-33 μR/h
33-68 μR/h
68-140 μR/h
140-280 μR/h
<280-560 μR/h

As the platform goes higher, the ability to detect deviations from the dominant background decreases.

Spatial resolution also decreases with altitude.

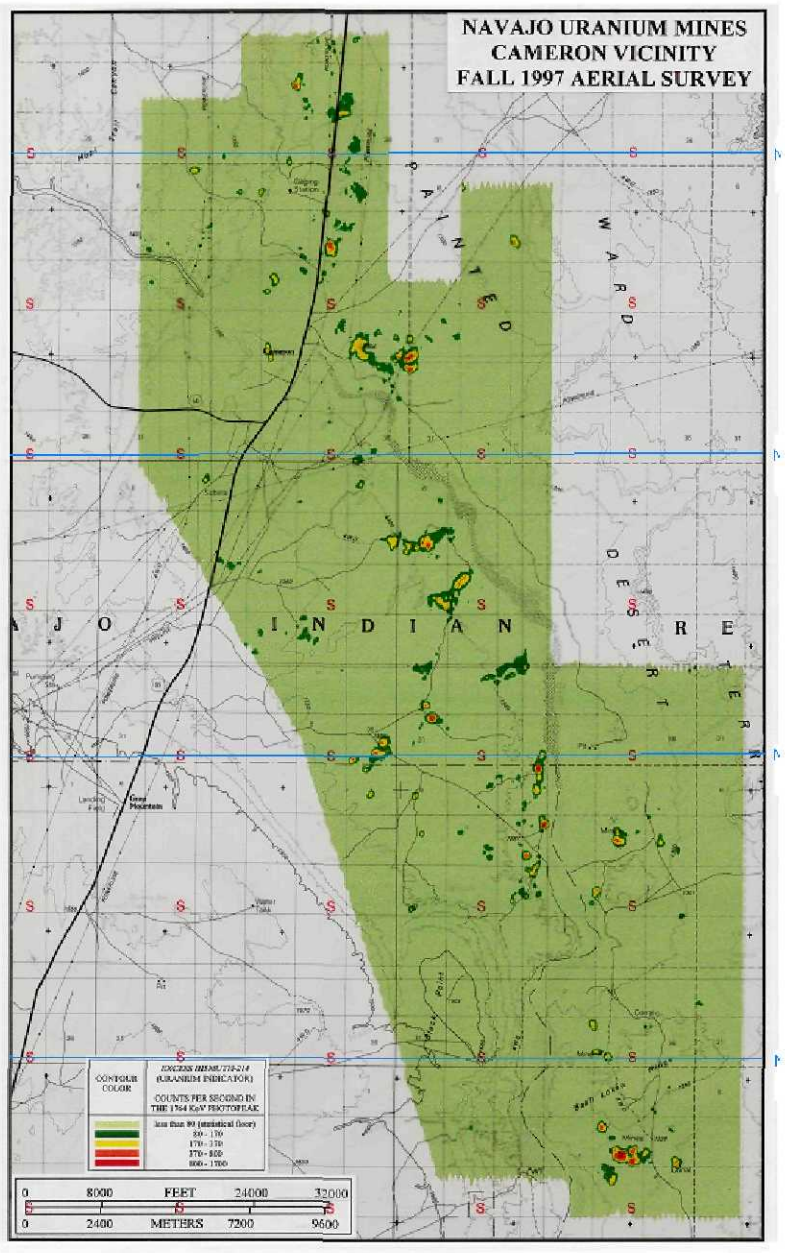
Detector Field-of-View Comparisons



For comparison, this slide shows the field-of-view (FOV) or area of coverage for three types of field measurements.

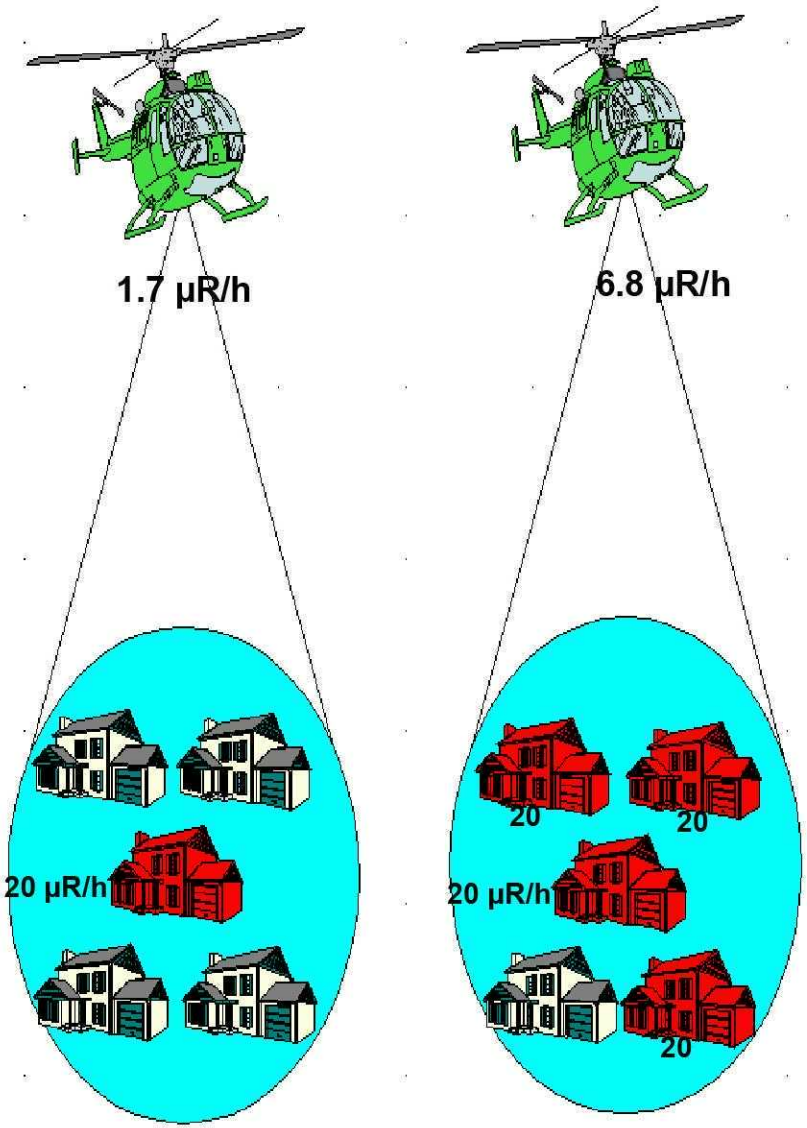
- **Aerial Survey** – flown at an altitude of 46 meters (150 ft)
  - FOV of 6570 m^2 (1.6 acres);
  - Ra-226 MDA = 1.5 pCi/g (based on Bi-214)
- ***In Situ* (Ground-Based) Measurement** – 60% n-type high resolution germanium (HPGe) detector (and/or a pressurized ionization chamber) mounted at a height of 1-m (3.3 ft)
  - FOV of 180 m^2 (0.05 acres)
  - Ra-226 MDA= 0.2 pCi/g (based on Bi-214, 15-minute sampling time)
- **Surface Area Deposition Soil Sample** – taken at a depth of 2.5 to 10.0 cm (1- to 4-inches)
  - FOV of 0.01 m^2 (2.4E-06 acre). Very, very small sampling area!
  - Ra-226 MDA= 1.0 pCi/g (True -- no daughters measured)

Sampling Density Considerations



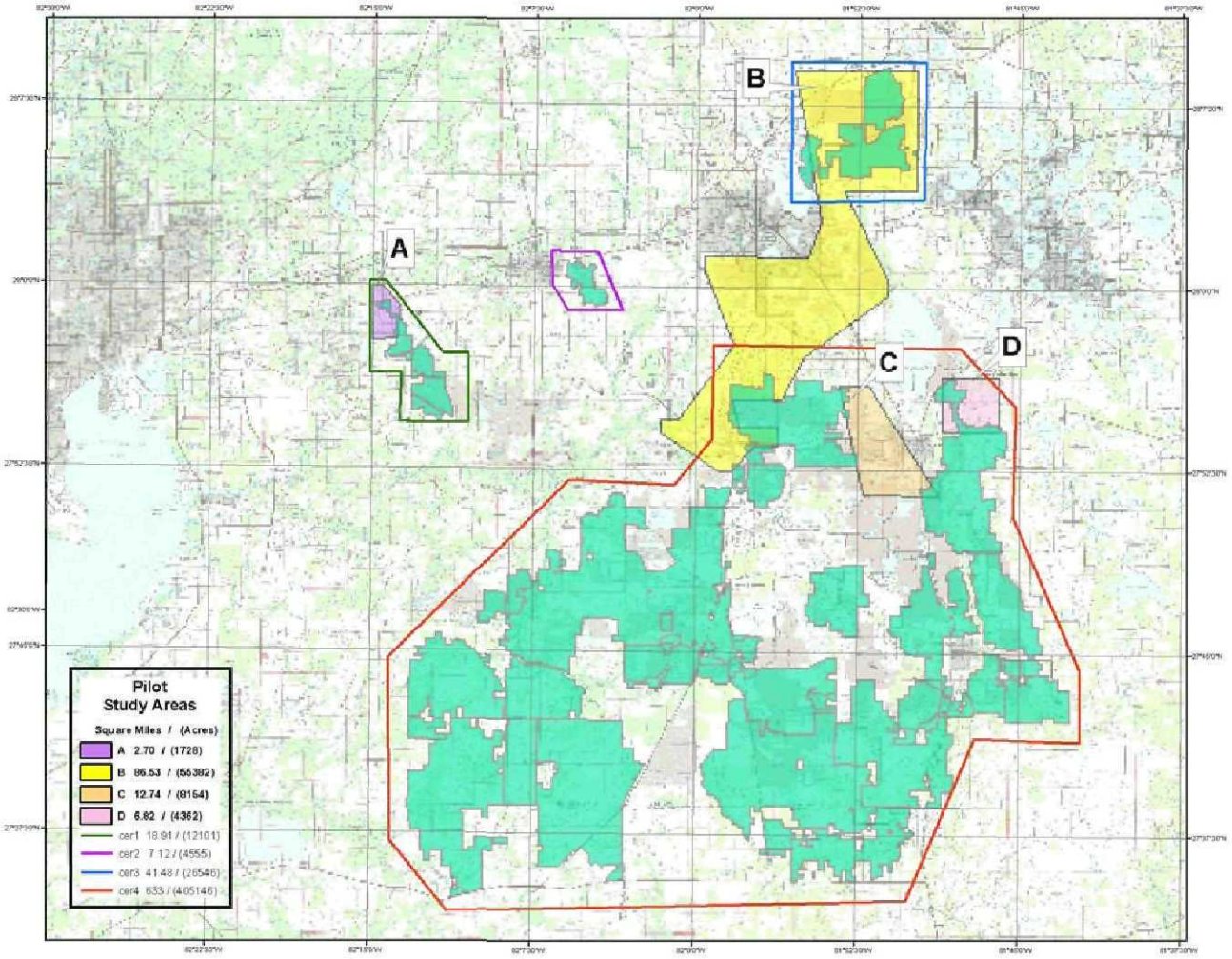
- The radiation contour map is from the aerial survey data collected during the 1994-1999 Navajo Uranium Mines Survey. Collection was at an altitude of 150 feet AGL and 300 feet line spacing.
- Red S symbols (at the nominal 3-mile sample spacing of the ground data taken by the 1986-1987 FIPR Florida survey) are overlaid on the Navajo data to estimate adequacy of the FIPR sample spacing for detecting small areas of elevated activity.
- Blue lines representing nominal NURE flight lines (6 mile spacing) are also placed on the figure for reference.
- If Florida mine activity is primarily from relatively small areas (like Navajo), FIPR data would not find/or properly characterize many impacted areas. This is probably why FIPR data disagrees with the higher activity levels found in the 1970s-1990s sub-division measurements made within known impacted areas. Because the NURE aerial data is integrated/summed every 250 feet along the flight path, the NURE data would be more likely than FIPR to see areas of elevated activity.

AMS Area Averaging Effect



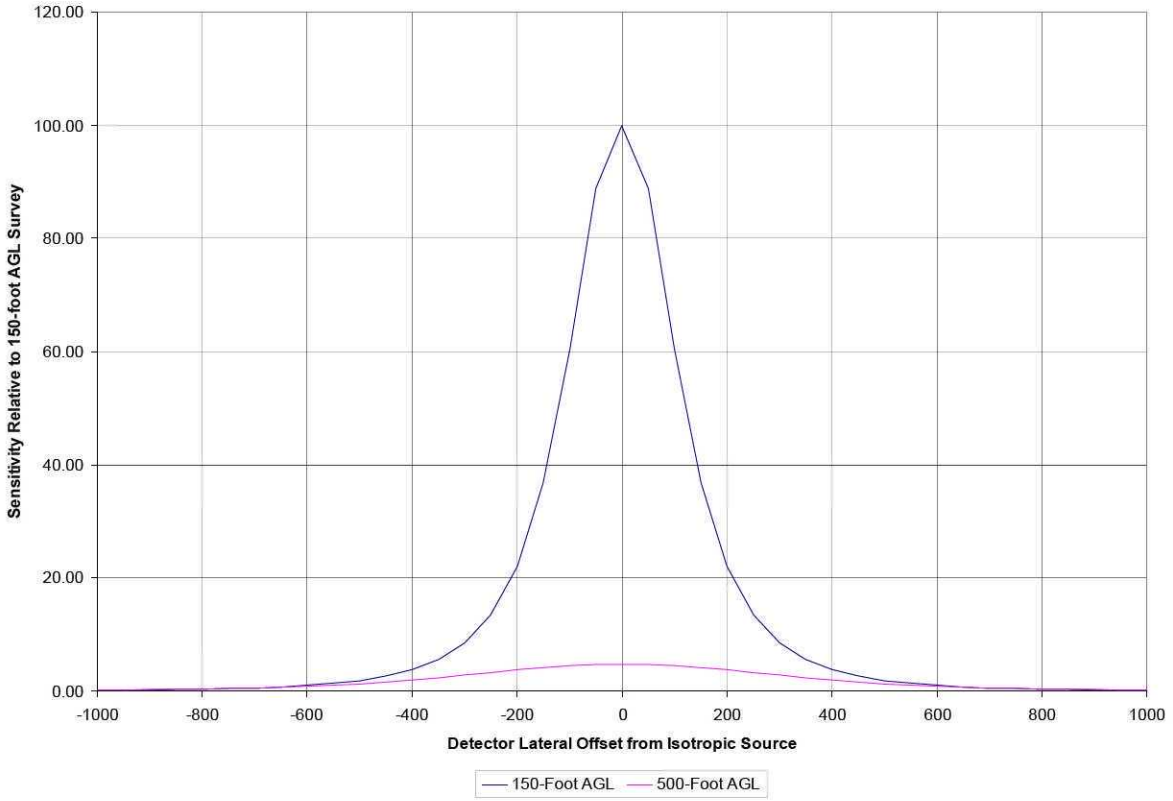
- Residential Home Site Area is ~ 0.3 acres
- AMS helicopter, flying at an altitude of 150 ft, has a footprint of ~ 1.6 acres. However, the effective field-of-view of the AMS radiation detection system is also dependent on the isotope-of-interest's photopeak gamma energy and its air mass attenuation. Hence, the actual field-of-view is somewhat larger than stated.
- As demonstrated, the area averaging effect yields an inferred aerial exposure rate approximately equal to a factor of 12 less than the actual exposure rates observed on the ground.
- For Ra-226 (specifically Bi-214) flying at an altitude of 150 ft, the minimum detectable activity (MDA) for the AMS radiation detection system is ~ 2.5 µR/h.

Florida Phosphate Mines CERCLIS Sites



- Four CERCLIS Survey Areas [outlined areas] 700.5 mi^2 (~ 448,350 acres)
- Bell-412 Helicopter with 12 16-x 4-x 2-in. NaI(T*l*) log detectors
- Proposed Survey Parameters
  - Altitude: 150 feet
  - Line Spacing: 1000 feet
  - Ground Speed: 80 knots
- Total # Flights: 30 (75 flight hours)
- Total # Field Days: 18 (assume team already deployed in the field and weather permitting)

AMS Detector Relative Sensitivity Comparison



Comparison of the relative sensitivity of the AMS radiation detection system at two survey altitudes – 150-ft and 500-ft above ground level (AGL)

- Typical Survey Line Space is 2 x Altitude
  - 300 feet for 150-ft AGL survey
  - 1000 feet for 500-ft AGL survey
- For an isotropic source, a 150-ft AGL survey would have equal to or superior sensitivity than a 500-ft AGL survey for lateral offsets up to 500 ft (*i.e.,* 1000 ft line spacing) due to the sideward-looking portion of the detector array.
- Hence, BN recommends flying the proposed CERCLIS sites at an altitude of 150-feet using a line spacing of 1000 feet.